Assessment of Economic Impact of Poor Power Quality on Industry

Sri Lanka

ᘙ **Nexant**

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ASSESSMENT OF ECONOMIC IMPACT OF POOR POWER QUALITY ON INDUSTRY

SRI LANKA

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Study Group

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List of Acronyms

ADB	Asian Development Bank
BUG	Backup Unit Generation
BOOT	Build Own Operate and Transfer
BOO	Build- Own - Operate
BOT	Build Operate and Transfer
CEB	Ceylon Electricity Board
CEnS	Centre for Energy Studies
CAIDI	Customer Average Interruption Duration India
EIS	Economic Impact Study
EMS	Energy Management Systems
GDP	Gross Domestic Product
LECO	Lanka Electric Company Ltd.
LNG	Liquefied Natural Gas
SCADA	Supervisory Control and Data Acquisition
SAIFI	System Average Interruption Frequency Index
TOE	Tonnes of Oil Equivalent
USAID	United States Agency for International Development
WB	World Bank

Acknowledgement

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- Ministry of Irrigation & Power, Sri Lanka
- Ministry of Industrial Development, Sri Lanka
- Ceylon National Chamber of Industries
- Federation of Chambers of Commerce and Industry of Sri Lanka
- Board of Investment, Sri Lanka
- Small & Medium Enterprise Developers, Sri Lanka
- Central Bank of Sri Lanka
- Sri Lanka Apparel Exporters Association
- Ceylon Electricity Board
- Hoteliers Association, Sri Lanka
- Lanka Electricity Company Ltd
- The Planters Association, Sri Lanka
- Ceylon Chamber of Commerce

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Executive Summary

Sri Lanka has been experiencing power shortages from time to time since the early 1990s mainly because of generation capacity shortages and the hydropower plants inability to compensate adequately during times of heavy droughts which come every four to five years. The extent of such power shortages has been increasing in recent years because of growing electricity demand, coupled with inadequate additions to thermal capacity additions in timely manner. In particular, during the last ten years, the new generation capacity as proposed in the long-term generation expansion plan of the Ceylon Electricity Board has never been implemented according to the time schedule. The resulting power shortages, have caused planned power interruptions and unplanned interruptions that have seriously affected the quality of power supply at the consumer-end. This situation is common to the whole of South Asia where the economies are significantly impacted by poor power quality.

Under the South Asia Regional Initiative/Energy (SARI/Energy) project of USAID, Nexant SARI/Energy, the technical assistance contractor, has undertaken to study and assess the economic impact of poor power quality on industry in the South Asia region, comprising the countries of Sri Lanka, Nepal, Bangladesh and India. The technical assessment evaluates the costs to the economies from higher energy costs and environmental impacts from Backup Unit Generation (BUG) and loss of production due to poor power quality & reliability.

This report presents the Sri Lanka component of the regional study.

The Sri Lanka study was confined to a sample consisting of 150 installations encompassing all subcategories of industries (Classification of the Central Bank of Sri Lanka) providing a significant contribution to the country's GDP. In addition the tea, and coconut processing industries and the hotel sector were also included in the sample.

The study found that the main economic impact of the power interruptions, both planned and unplanned, is the loss of output in the industrial sector. These losses can be as high as approximately US$ 81 million annually (**0.65%** of GDP) under a typical scenario of imposing power interruptions resulting from system generation capacity shortages such as those experienced during 2001. Also the impact due to unplanned outages can be around US$ 45 million (**0.3%** of GDP) in a typical year not experiencing regular planned interruptions such as those in 2001. This is undoubtedly a significant economic loss especially in comparison to the **4.5 %** to **5%** average GDP growth in the country during the last few years.

The economic losses due to planned and unplanned due to planned and unplanned power interruptions can also be expressed in other forms. One of the commonly used is the economic loss (in US$) per unit of supply loss (kWh); identified as the cost of unserved energy.

The cost of unserved energy for the Sri Lanka system:

Interruption Type	Cost of Unserved Energy
Planned Interruption	US$ 0.66 (Rs.59)
Unplanned Interruption	US$1.06 (Rs.97)

No installation complained of any voltage or supply harmonic problems but almost all had comments that the high electricity tariff was affecting their competitiveness in the market.

In addition, it was found that **92%** of the sampled industries have backup unit generation facilities to satisfy either their full or partial demand for power. The total backup unit generation capacity in the Sri Lanka electricity sector is expected to grow during the next five years if the present trend of using such generation facilities continues to hold at the penetration levels found in the sample. This can be as much as 170 GWh per annum during the next five years. Such a situation results not only in increased energy costs to industry but also incremental emissions in the sector, which would badly affect the local environment, particularly in urban centres where most of these industries are located.

These findings emphasise the importance of reducing both planned and unplanned interruptions in the Sri Lanka power system to minimise the impact on the economy. To achieve this objective the following actions are recommended.

- Streamlining of generation capacity additions including using efficient procurement processes and encourage private sector participation in different forms.

- Adoption of effective demand-side management strategies while encouraging the consumers to use backup unit generation facilities to the maximum, in the immediate future to address capacity shortage. This requires incentives in the electricity tariff structure.

- Operate the generation, transmission and distribution system in a more reliable manner through regular maintenance of the facilities and with the use of proper management systems in the operations.

- Inclusion of the standards on power quality in the electricity act so that the utilities are obliged to pursue different alternatives to make sure that the quality of supply is maintained for the benefit of consumers

It is also recommended that studies that enhance the reliability of the Sri Lanka national power grid, including a study on present planning and operations be undertaken.

The growing demand for energy, and electricity in particular, has led to a precarious balance of supply and demand. More often in the recent past, this effect has been on the demand side of the supply-demand equation and has therefore, caused the need for remedial actions such as load shedding and demand reduction. Even as most countries develop, an inevitable consequence is their increasing dependence on electricity. In fact, studies have shown that a positive co-relation exists between the per capita commercial energy consumption and the state of economic development within a country. In this sense, a poorly developed country uses less commercial energy and a highly developed country uses more commercial energy on a per capita basis.[1] Noting that the economy of a country is ubiquitously tied to the use of electrical energy, it is expected that a lack of the same would have a negative impact on the economy and hence GDP of that country. Using the same logic, it is also expected that poor power quality in the form of planned or unplanned power supply interruptions will have an adverse impact on the GDP of a country.

Figure 1.1 shows the strong co-relation between power shortages (effective demand satisfied) and the economic activity in Sri Lanka, for the period 1984-98. When the economy of the country was seriously affected due to the social uprising in 1989/90 the electricity demand shrank drastically while the power shortages in 1996 resulted in a substantial reduction in the economic growth rate. Therefore, it is understood that any unfavourable gap between the demand and supply of electricity in the country adversely affects the country's economy.[2]
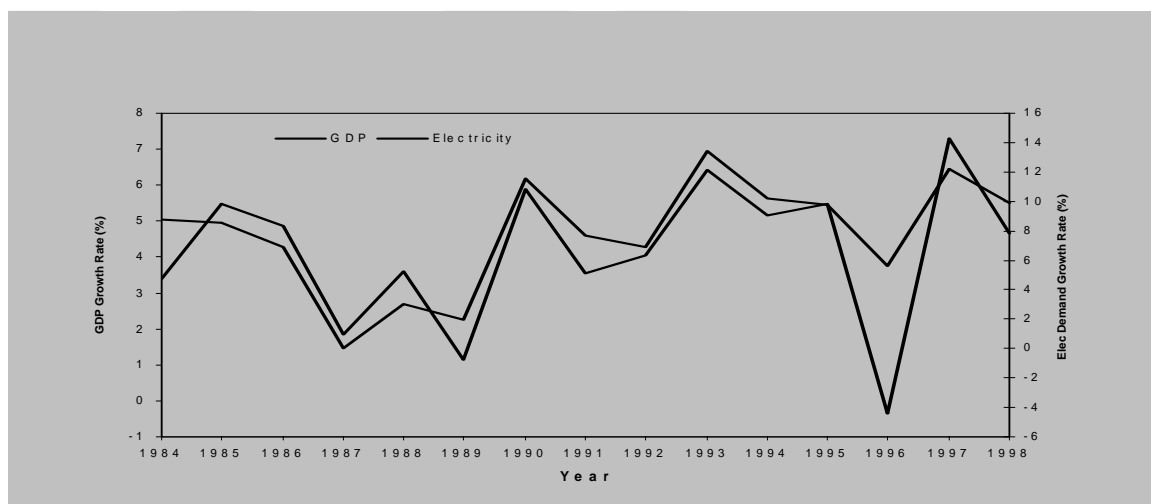
Source: CEB: Generation Planning Division

Figure 1.1. Correlation between electricity demand and economic activity

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[1] UNDP(Oxford University Press 2001), Human Development Report
[2] WJLS Fernando & AR Ramasinghe, "Impact of Casual Factor of !996 Power Crisis".

This report presents the results of a study of the economic impact of poor power quality on a sample set of industries in Sri Lanka and extrapolates the results to estimate the effect of poor power quality on overall GDP of the country.

This task, sponsored by USAID, is one of the many tasks being carried out under the aegis of the SARI/Energy project, which aims to promote mutually beneficial energy linkages among the nations of South Asia. To help unlock the energy potential of South Asia, SARI/Energy focuses on[3]:

- Regional Energy Trade and Exchange
- Regulatory and Tariff Policy Reform
- Private Sector Involvement
- Rural and Renewable Energy Supply
- Energy Efficiency

Under the SARI/Energy project, Nexant SARI/Energy, the technical assistance contractor, has undertaken to assess the economic impact of poor power quality on industry in the South Asia region, especially in the countries of Sri Lanka, Nepal, Bangladesh and India. The technical assessment evaluates the costs to the economies from higher energy costs & environmental impacts from Backup Unit Generation and loss of production due to poor power quality & reliability.

This report is the first such country assessment.

The report is intended to provide a better understanding of the problem to: the utility staff at CEB and LECO, in order for them to consider immediate and long-term remedial action; policy-makers to consider amendments to the existing policy and guidelines; and stakeholders, so as to widen the agenda and strengthen end user participation in the electricity supply industry in the country.

The remainder of this section presents background information on the energy situation in Sri Lanka and focuses on specific issues related to electric power and the problems caused by poor power quality.

Section 2 defines the scope of the Economic Impact Study (EIS) as outlined in the SARI/Energy project objectives.

Section 3 of this report outlines the study methodology and presents the basis for sample selection and the choice of samples for purposes of this study.

Section 4 presents the results of the survey and its analysis in detail. Economic impacts of poor power quality, expected increase in BUG and the environmental impacts are all quantified and presented in this section.

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[3] SARI/Energy website: http:// sari-energy.org

Section 5 presents a discussion of the results and extends the analysis to include the expected national economic and other impacts of poor power quality in the Sri Lanka power system.

Conclusions and recommendations for short-term actions are outlined in sections 6 and 7 respectively.

All supplementary information is included in the Appendix.

1.1 Energy Sector in Sri Lanka

Sri Lanka's energy supply of an estimated 8.7 million tonnes of oil equivalent (TOE) in 2000[4], was composed of three main primary energy sources; biomass, hydropower and petroleum. Of these sources biomass has been the most dominant, contributing to over **50 %** of the total supply; a trend that is likely to continue into the foreseeable future. Hydropower, the main primary source used for electricity generation in Sri Lanka contributed **12%** of the total energy supply. The absolute energy output from hydropower is likely to remain fixed with only very little new additions to the generation system expected in the future due to the poor economic viability of projects harnessing the remaining estimated hydro potential of about 800 MW. The remaining contribution of over 37 percent was obtained from petroleum products as shown in Figure 1.2
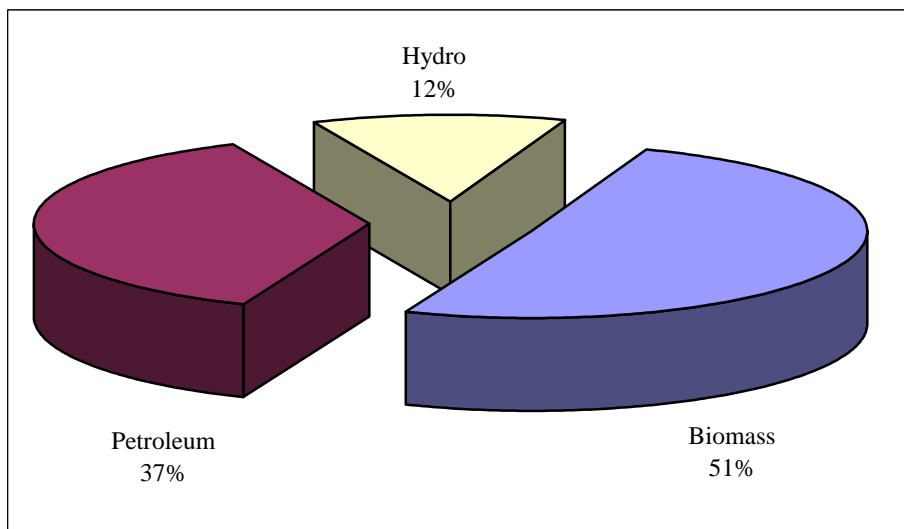
Source: Sri Lanka Energy Balance - 1999

Figure 1.2. Primary Energy Supply Contributions in Sri Lanka

Given the economic limitations of hydropower development and the social issues associated with biomass usage, it is expected that the projected increase in energy usage, estimated at an annual **4%** growth rate, will be met by petroleum and coal. A major component of the projected increase in primary energy requirements can be attributed to the electricity generation and transport sectors.

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[4] Estimated using extrapolated data from the Sri Lanka Energy Balance -1999

1.2 Power Sector in Sri Lanka

The power supply industry in Sri Lanka is a vertically integrated system mainly owned by the government with the exception of few generating stations owned and operated by the private sector. State owned Ceylon Electricity Board (CEB) owns and operates a large majority of the generating stations, transmission system and almost **90%** of the distribution system. Lanka Electricity Company, whose majority stock is held by the CEB, owns the remaining **10%** of the distribution system.

Electricity Demand

The overall annual electricity demand grew from 823 GWh in 1972 to 5416 GWh in 2000 at an annual compound growth rate of about **7%**. The growth during the period 1972-1977 was at an average annual rate of **4.7%** while it sharply increased to **10%** per annum in the period 1978 to 1982. However, between 1982 and 1989, the growth rate dropped to **4.9%** and then increased again to **8.9%** from 1989. The annual growth rate is expected to be about **8% -9%** in the next decade.[5]

The country wide electrification level stands approximately at **57%** of the households or about 2.3 million houses in the country with a relatively large percentage of rural households not being connected to the national grid. There is a vast disparity of electrification levels across the country with almost complete electrification in the district of Colombo while remote districts, such as Ampara and Monaragala, record levels of electrification less than **20%.**

The total electricity consumption of about 5416 GWh in 2000 has been contributed by the industrial sector (**39.8%**), household sector and religious places (**39.2%**), and the commercial sector (**20.3%**).[6]

Electricity Generation

The use of hydroelectricity in a particular year entirely depends on the availability of effective installed capacity and rainfall in catchment areas. CEB's generation plan opts for the usage of oil-fired thermal plants only if there is still an energy requirement after all hydro resources have been utilised.

The total hydro electricity generation capacity of about 1150 MW in existing power stations contributed about 3197 GWh to the electricity supply in 2000. Though there is an estimated maximum potential of about 2000 MW hydropower, exploitation of the remaining potential is constrained by economic factors. Thermal generation plants with an installed total capacity of 685 MW supplied 3486 GWh in 2000. This includes utility

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[5] CEB, 1999: " Long Term Generation Expansion Plan 2000 – 2017
[6] CEB: Statistical Digest 2000.

owned generation, independent power production and captive generation. Additionally, a 3 MW pilot wind turbine plant in the south coast of Sri Lanka produced 3.5 GWh in same year.[7]

Forecasts of annual electrical energy generation for the period 2002 to 2017 are given in figure 1.2. Expansion of the hydroelectric system during this period is limited to an installed capacity of 70 MW, producing 305 GWh. This implies that there will be a significant difference between the demand for power and hydropower output, which will need to be bridged by thermal plants, which are either oil or coal based according to the present generation plan.[8]
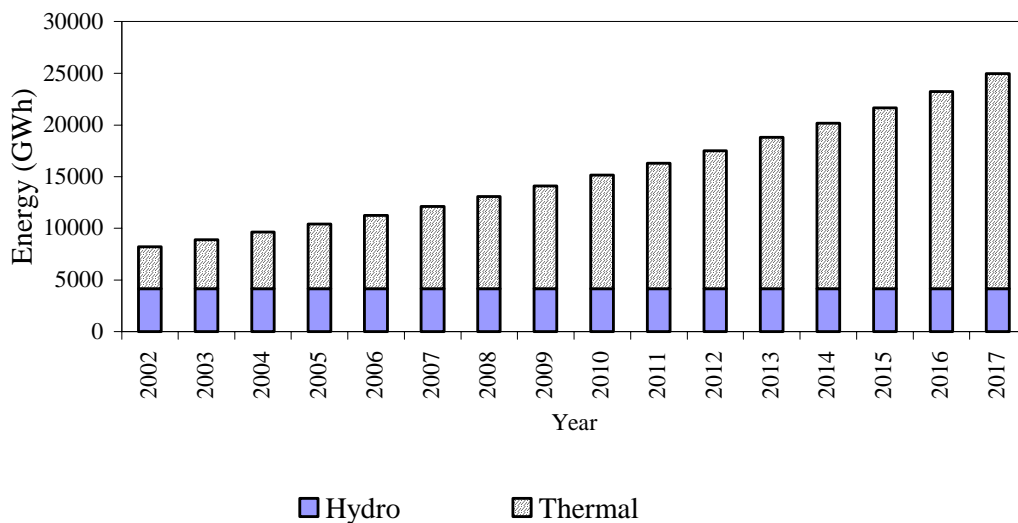
Figure 1.3: Growth of the Electricity Generation Sector 2002-2017

System Losses

Total system loss, which includes technical losses such as generation station use, transmission and distribution network losses, and non-technical losses such as unmetered consumers, amounted to approximately **21%** of the total generation. It is important to note that the system losses have been increasing during the last three years. The system losses were **18%**, **19 %** and **21%** in the years 1997, 1998 and 1999 respectively.[9],[10] Though these system losses are substantially lower than in almost all other countries in South Asia, it is still too high to be acceptable as a reasonable system loss. One of the main reasons behind these high losses is the large number of non-metered consumers, totalling approximately 300,000. Furthermore, the extension of distribution lines beyond technical limits has also contributed to high network losses.

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[7] CEB: Statistical Digest 2000.
[8] CEB1999: Long Term Generator Plan 2000-2017.
[9] ECF: Sri Lanka Energy Balance-1999.
[10] CEB: Long Term Generator Plan: 2000-2017

Power Sector Reforms

Currently there is a World Bank and Asian Development Bank assisted ongoing program on power sector restructuring. The proposed electricity industry structure envisages vertical separation of generation, transmission and distribution functions and establishment of an independent regulator for the industry. A new Electricity Act incorporating these new structures has been already drafted and is to be presented to the Parliament of Sri Lanka in the near future.[11]

1.3 Regional Comparison

Table 1.1 shows that the per capita consumption of electricity in Sri Lanka in 1998 was 244 kWh (Approximately 280 kWh in 2000). This is relatively low in comparison to India and Pakistan.

Table 1.1:   Per capita electricity consumption in the SAARC Region

Country	Electricity Consumption (kWh per capita)	
	1980	**1998**
India	130	384
Pakistan	125	337
Sri Lanka	**96**	**244**
Bangladesh	16	81
Nepal	13	39

Source: EIA website: http://www.eia.doe.gov

1.4 Power Shortages

Since the early 1990s, Sri Lanka has been experiencing power shortages from time to time mainly because of a shortage of hydropower resulting from severe drought conditions. While these droughts have been occurring once every four to five years, the intensity of the resulting power shortages has been increasing in recent years, because of the ever-growing electricity demand coupled with inadequate thermal capacity additions. In particular, during the last decade the implementation of capacity additions as proposed in the long-term generation expansion plan of the Ceylon Electricity Board has been always delayed. The worst power shortages occurred in 1996 and in 2001 when rotating power interruptions (Load Shedding) were introduced to reduce the daily demand in order to facilitate proper grid operation. Approximately 300 hours of load shedding had already

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[11] Ministry of Power & Energy, Sri Lanka, 1998: Power Sector Policy Directives

been planned by the CEB for the year 2001 to cope with the imbalance in the power supply-demand equation.

These power shortages occurring now almost on a regular basis emphasise the need to have alternative forms of power supplies, particularly for meeting the needs of the commercial and industrial sectors where the effects of such shortages are likely to be substantial economic losses. Most of the large and medium scale installations in these sectors have opted for backup unit generation, (BUG) to satisfy atleast partially the essential electricity requirements of individual installations. Installation of smaller backup unit generators, even in the domestic sector, has started becoming a common occurance.

1.5 Government Regulations on Power Usage

In Sri Lanka, under normal conditions, there are no restrictions on the use of utility supplied electricity in the country. However, during times of power crises, generally resulting from poor hydropower generation, CEB imposes usage restrictions. Usage restrictions may include banning the use of power drawn from the national grid for purposes of air conditioning and advertising using neon display boards. Such government-imposed restrictions can have a substantial impact on local businesses. In 2001, the government introduced such restrictions to reduce electrical demand .

Power outages, due to system deficiencies resulting from supply constraints and reliability issues, have largely led to poor power quality. This situation is prevalent, not only in Sri Lanka as noted in the earlier section, but also in the rest of the SARI/Energy countries. Consequently such power quality problems have had a detrimental effect on local economies and the entire South Asian region in general.

In the context of Task 9 of the USAID sponsored SARI/Energy project, Nexant has undertaken to study and assess the economic impact of poor power quality on industry in the South Asia region, especially in the countries of Sri Lanka, Nepal, Bangladesh and India. The assessment estimates the costs to the economies from higher energy costs & adverse environmental impacts from back up generation as well as loss of production due to poor power quality & reliability.

The report is intended to provide a better understanding of the problem to: the utility staff at CEB and LECO in order for them to consider immediate and long term remedial actions; policy makers to consider amendments to the existing policy and guidelines; and stakeholders, so as to widen the agenda and strengthen the end user participation in the electricity supply industry in the country.

The major elements of the technical assessment are:

- Review existing guidelines.
- Analyse power quality for the identified samples of customers.
- Estimate the cost of poor power quality to the economy from lost production and high-energy costs & environmental impacts from Backup Unit Generation.
- Estimate the anticipated self-generation over the next five years and the cost over the same period.
- Provide recommendations for immediate & long-term power quality improvements.
- Propose improvements for existing policy and guidelines based on results of the assessment.

3.1 Organisational Structure

The study was organized to fit into the following structure to ensure that all necessary inputs to the study are incorporated and coordinated properly to achieve its final objective. Figure 3.1 shows the organizational structure of the various team members who contributed to this study.

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                    │   Task Manager   │
                    │     NEXANT       │
                    │   SARI/Energy    │
                    └────────┬─────────┘
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│  Consultant  │    │   Local Study    │    │ Stakeholder  │
│   NEXANT     │───▶│      Team        │◀───│  Committee   │
│ SARI/Energy  │    │     Leader       │    │              │
└──────────────┘    └────────┬─────────┘    └──────────────┘
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                    ┌────────▼─────────┐
                    │      Local       │
                    │    Technical     │
                    │  Team Members    │
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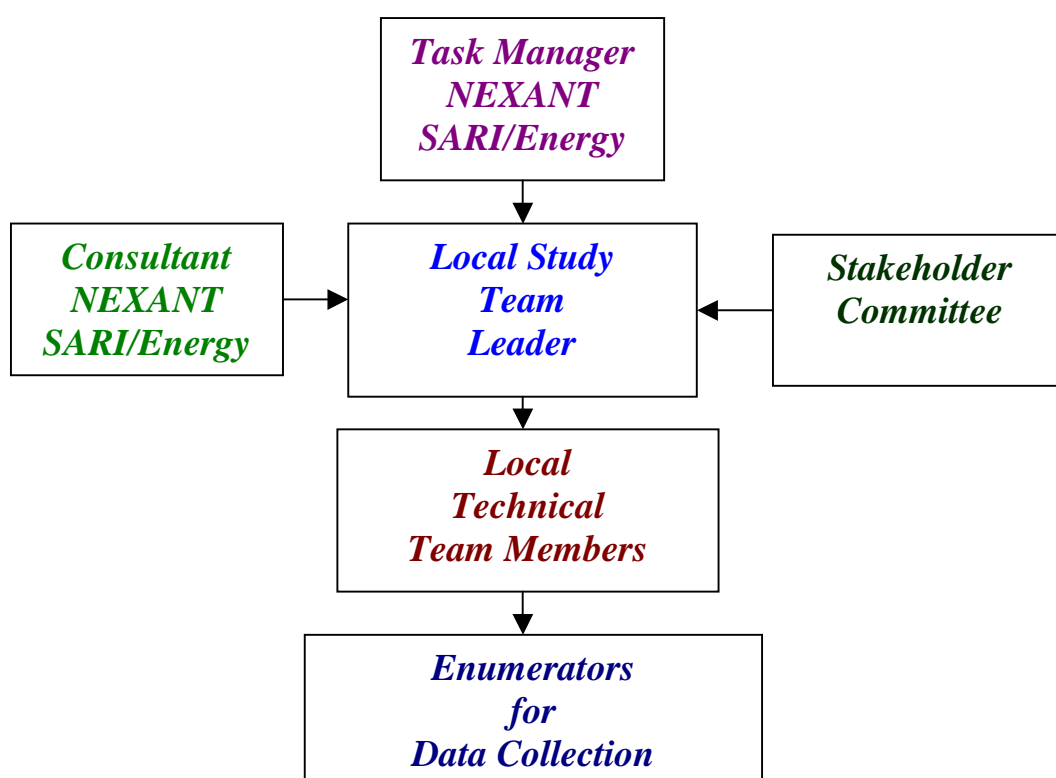
Figure 3.1: Organizational Structure of the Study

The local study team inclusive of the enumerators consisted of individuals from the Centre for Energy Studies at the University of Moratuwa (CEnS).

The stakeholder committee comprised senior managers from the stakeholder institutions including Ceylon Chamber of Commerce, Ceylon National Chamber of Industries, Federation of Chambers of Commerce and Industry of Sri Lanka, Small & Medium Enterprise Developers, Sri Lanka Apparel Exporters Association, Hotel Association and the Planters Association.

3.2 Study Methodology

Figure 3.2 shows the major steps of the adopted study methodology. The study plan and methodology were first conceived and presented to the stakeholders in May 2001. After incorporating inputs from the stakeholders, the sample plan and questionnaire were finalized. The population was characterized and the samples selected based on the considerations listed in Section 3.4. Using the developed questionnaire, data enumerators from the Centre for Energy Studies (CEnS) performed site visits to obtain the required data from each participant. Data that was obtained from the field research was centrally archived for analyses and reporting. Stakeholder input was solicited at each stage of the planning and implementation process to ensure that practical issues were not overlooked.
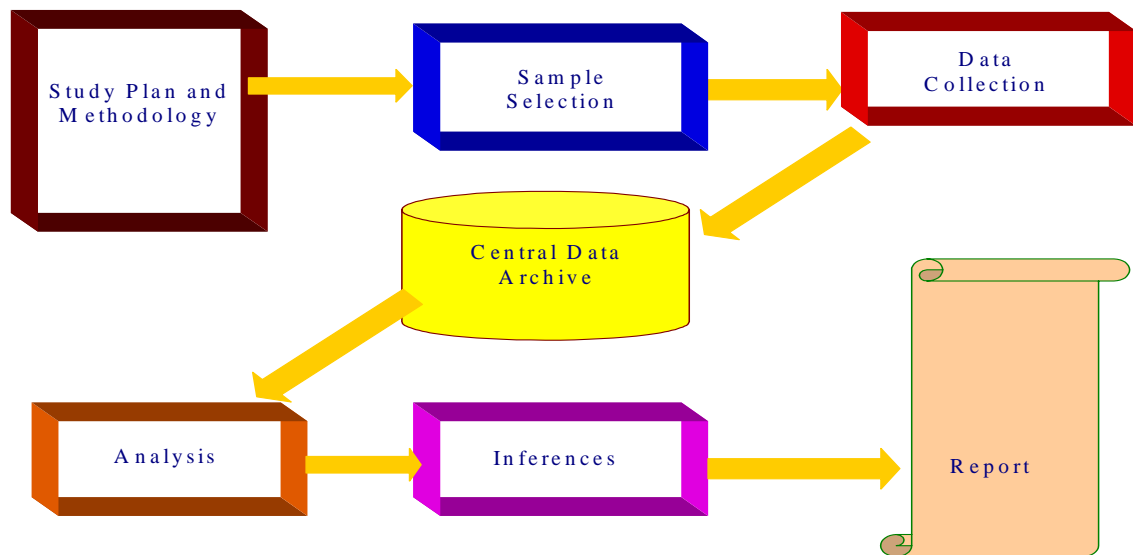
Figure 3.2: Study Methodology

3.3 Population Characterization

Using the standard industry classification published by the Central Bank of Sri Lanka, (Categories 1-9 in Table 3.1),[12] various contributors to the GDP were noted and listed in order of their absolute and percentage contribution to the GDP. Noting that some categories contributed very little to the GDP and that there were only a handful of those contributors, the study focussed on those categories that contributed more than **4 %** to the total GDP. In addition to these categories, Tea, Rubber and Coconut Processing Industries and Hotels were included in the study due to the widespread nature of their

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[12] Central Bank of Sri Lanka: Annual Report 2000.

operations in the country. The GDP contribution of each of these categories in year 2000 is shown in Table 3.1.

Table 3.1: GDP Contribution of each industry category considered

Categories	GDP US$ Million	Percentages
1) Food, Beverages & Tobacco	545	22%
2) Textile, Wearing Apparel & Leather Products	772	32%
3) Wood and Wood Products	17	1%
4) Paper and paper products	31	1%
5) Chemical, Petroleum, Rubber & Plastic Products	197	8%
6) Non Metallic Mineral Products	158	7%
7) Basic Metal Products	11	0.4%
8) Fabricated Metal Products, Machinery, Transport Equipment	86	4%
9) Products not specified elsewhere	44	2%
10) Tea	158	7%
11) Rubber	23	1%
12) Coconut	133	5%
13) Hotels	250	10%
Total	**2425**	**100%**

Source: Central Bank of Sri Lanka: Annual Report 2000.

3.4 Statistical Sampling

Due to budgetary, time and manpower limitations, the total sample size for the study was set at 150. Consequently, industrial categories that did not have significant contributions to the annual GDP were removed from the sampling population. This resulted in the removal of the following four categories whose GDP contribution is shown below in parentheses:

- Wood and wood products (**1%**)

- Paper and paper products (**1%**)

- Basic metal products (**0.4%**)

- Products not specified elsewhere (**2%**)

- Rubber (**1%**)

After this initial filtering from the overall population, a total of 3074 industrial installations remained. Table 3.2 shows the study categories and the number of industrial installations in each category that remained.   A total of 150 samples were then selected from this remaining population, consisting of a total of 3074 industrial installations spread over 8 distinct categories and 16 sub-groups.

Table 3.2: The industry population used in the study

No.	Industry Type	Industry Population	
1	**Food, Beverage & Tobacco**	321	
1.1	Food & Other		287
1.2	Liquor		18
1.3	Beverage		8
1.4	Tobacco		8
2	**Textile & Leather**	728	
2.1	Apparel		497
2.2	Textile		169
2.3	Leather		62
3	**Chemical, Petroleum, Rubber & Plastic Products**	521	
3.1	Chemical		41
3.2	Rubber		138
3.3	Plastic		193
3.4	Pharmaceuticals		147
3.5	Petroleum		2
4	**Non Metallic Mineral**	143	
4.1	Diamond		20
4.2	Ceramic		33
4.3	Cement		12
4.4	Building		78
5	**Fabricated Metal, Machinery, Transport Equipment**	349	
6	**Tea**	745	
7	**Coconut**	60	
8	**Hotels**	207	
	Total	**3,074**	

In order to have a fair representation of the population, this final sample set of 150 was chosen randomly from the categories and sub-groups shown in table 3.2. The number of samples chosen from each category for the first five categories was based on the proportion of the total countrywide number of installations in that category. For the remaining three categories, the rest of the samples were distributed in the proportion of number of industries in each category.

Figure 3.3 shows the final number of samples from each industrial category after the filtering process. Given the criterion for sample selection from the first five categories,

the number of samples from the Textile and Leather category is the largest. Similarly, the number of samples from the Tea category is the largest among the last three categories.
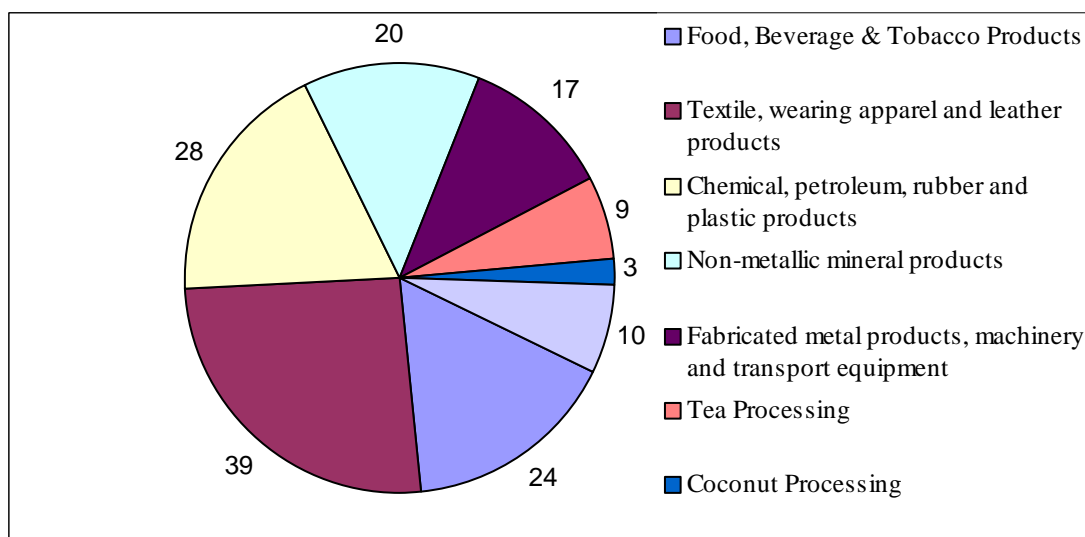

Figure 3.3 Composition of the Selected Sample

Industrial consumers, who are supplied electricity in bulk at varying electricity intensity, were included in the sample selection to ensure a proper representation of the industry in Sri Lanka. For instance, both high electricity consuming industries such as cement, glass and ceramic manufacturing facilities and low electricity consuming industries such as garment and liquor production facilities were included in the categories to be studied.

3.5 Questionnaire

In order to gather all the relevant information to effectively satisfy every element of the project scope, a questionnaire was designed in conjunction with the stakeholders' inputs. Appendix 1 contains the complete questionnaire. Power quality problems were classified as due to planned and un-planned power outages. Further momentary outages were considered as an integral part of un-planned outages. The effect of voltage fluctuations and harmonics was also included in the questionnaire also. The questionnaire used for the survey covered the following areas of information.

- General Information on the industry installation such as the contact information and category of industry.
- Electricity consumption information based on monthly metering data.

- Financial information such as the annual value addition of each industry installation.
- Revenue losses due to sudden interruptions (Momentary Losses), un-planned longer interruptions and planned interruptions such as imposed power cuts during the times of power shortages.
- Revenue losses due to voltage variations beyond allowable limits, those due to harmonics in the electricity supply and those resulting from supply restrictions such as the ban on using air-conditioners connected to the grid supply during certain periods of the year.
- General comments given by the industry on the electricity supply and
- Technical information associated with any backup unit generators installed in the industry premises

The information to be collected was sub divided into different categories of losses such as those associated with raw material, manpower, production output and backup unit generator usage for convenience in data gathering.

3.6   Data Collection and Data Organization

Data collection was carried out through personal visits to each industrial installation selected in the Sample.   The enumerators, who were newly graduated electrical engineering students employed by the CEnS, were trained on the data requirements and collection procedures before being sent to the field for data collection.

Collected data were processed separately for different types of interruptions and other supply quality problems such as voltage variations and harmonics. Within each of these, the contribution to losses by raw material, output and manpower was tabulated separately. All the generator data was also processed and tabulated in a separate worksheet.

3.7 Data Analysis

Data collected for each category of power interruptions and other power quality problems were analysed to obtain the average values and their variances for each category within the sample. This led to the losses for momentary interruptions determined in terms US$ per each interruption regardless of the duration for each category while the losses due to planned and longer unplanned supply outages were calculated in terms of US$ per hour of interruption duration.

No industry reported any financial losses associated with the supply harmonics while only **16%** of the installations in the sample indicated possible losses in the event of voltage variations. But none of these installations had experienced any serious voltage problems during their operations. Furthermore, no industry reported any losses due to constraints on the use of electricity such as the banning of air-conditioner use with grid supply during times of power shortages. Therefore, these two power quality problems in the study and the effect of supply constraints were excluded during the detailed analysis that followed.

In order to estimate economic losses from the collected financial loss data, a conversion factor of 0.76 (obtained from the Ministry of Finance and Planning) was used in the analysis. As an example, a financial loss of US$ 100 is equivalent to an economic loss of US$ 76.[13]

When extending the economic values of different types of losses to cover the national scenario, it is important to examine the co-relation of the values obtained during the sample survey with the national figures. The ratio of value addition determined for each industry category with sampled data against the national GDP contribution reported for the same category is used as an indication to obtain the country wide average losses for each category of industries. This scaling is important since the sample cannot capture all possible types of industries and hence give wide variances for the average values.

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[13] In early 1990s, the Ministry of Finance and Planning carried out a study to estimate the ratio between the financial and economic costs of different expenditure streams in the Sri Lankan economy. The ratios applicable to the industrial sector vary due to the fact that the taxes and subsidies differ depending on the types of factors of production used in the manufacturing process. This study finally estimated an average ratio, 0.76, applicable to various sectors across the economy, which, is used in this analysis of economic cost of power supply outages.

The results of this study are presented in the form of expected average losses experienced by participants in the sample. Based on the structure of the questionnaire, the losses due to loss of raw material, manpower and output are quantified in terms of monetary values and presented by category. In this study, results of poor power quality losses are presented for planned and unplanned interruptions. Further, among unplanned outages, momentary losses are examined closely.

4.1 Average Industry Losses

Based on the analysis presented in section 3.7, the weighted average values of losses in different industry categories may be calculated. These results for individual categories are given in Table 4.1.

Table 4.1: Economic losses due to supply interruptions in each industry category

Average Losses (US$)			
Industry Category	Momentary (US$)	Planned (US$/hr)	Unplanned (US$/hr)
1. Food, beverage and tobacco products	301.61	153.39	363.24
1.1 Food and Other	211.68	166.18	279.28
1.2 Liquor	2.60	7.41	7.41
1.3 Beverage	139.48	160.67	160.67
1.4 Tobacco Products	4362.88	15.55	4378.43
2. Textile, wearing apparel and leather products	121.55	107.94	186.36
2.1 Apparel	120.99	81.77	161.25
2.2 Textile	109.87	133.55	198.70
2.3 Leather	157.93	247.98	354.08
3. Chemical, petroleum, rubber and plastic products	155.57	83.12	217.90
3.1 Chemicals, Paints and Fertilisers	220.98	315.81	315.81
3.2 Rubber	66.63	56.97	110.07
3.3 Plastic and PVC	187.17	110.17	288.27
3.4 Pharmaceuticals, Detergent and Other	179.52	4.55	199.49
3.5 Petroleum Products	0.00	65.00	65.00

4. Non-metallic mineral products		169.32	108.08	266.51
4.1	Diamond Processing	50.48	50.99	50.99
4.2	Ceramic Products	100.02	98.34	171.81
4.3	Cement	782.39	581.59	1636.31
4.4	Building Materials and Other	134.79	54.00	151.10
5. Fabricated metal products, machinery and transport equipment		125.25	415.90	429.31
6. Tea Industry		4.23	21.75	21.75
7. Coconut Industry		0.82	75.17	131.20
8. Hotel Industry		0.00	25.57	25.57

The monetary values given in Table 4.1 for momentary interruptions, are those associated with each such interruption regardless of the duration of the interruption period. In case of planned and longer term unplanned interruptions, the losses become a function of time. The national proportions of outage costs in different industry categories for planned and unplanned interruptions are given in Figure 4.1 and Figure 4.2.

In cases of both planned and unplanned interruptions, the main contribution to the national economic losses comes from the following four categories of industries.

- Food beverages and tobacco products
- Textile, wearing apparel and leather products
- Chemical, Petroleum and Plastic products and
- Fabricated metal products, machinery and transport equipment.

Further, the contributions from the coconut and hotel industries are relatively small in comparison to others. The significance of these contributions depend on two factors, the number of industry installations in each type and the effect of supply outages on the processes.
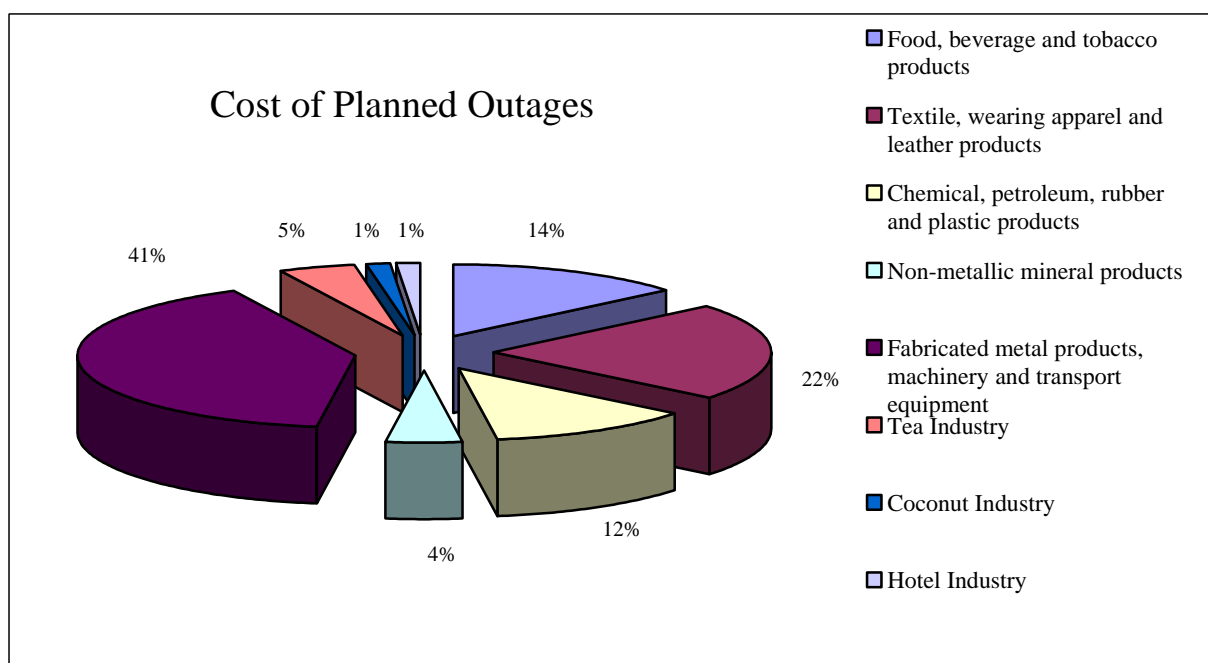
Cost of Planned Outages

Food, beverage and tobacco products

Textile, wearing apparel and leather products

Chemical, petroleum, rubber and plastic products

Non-metallic mineral products

Fabricated metal products, machinery and transport equipment

Tea Industry

Coconut Industry

Hotel Industry

Figure 4.1: Proportions of Cost of Planned Outages

Cost of Unplanned Outages

Food, beverage and tobacco products

Textile, wearing apparel and leather products

Chemical, petroleum, rubber and plastic products

Non-metallic mineral products

Fabricated metal products, machinery and transport equipment

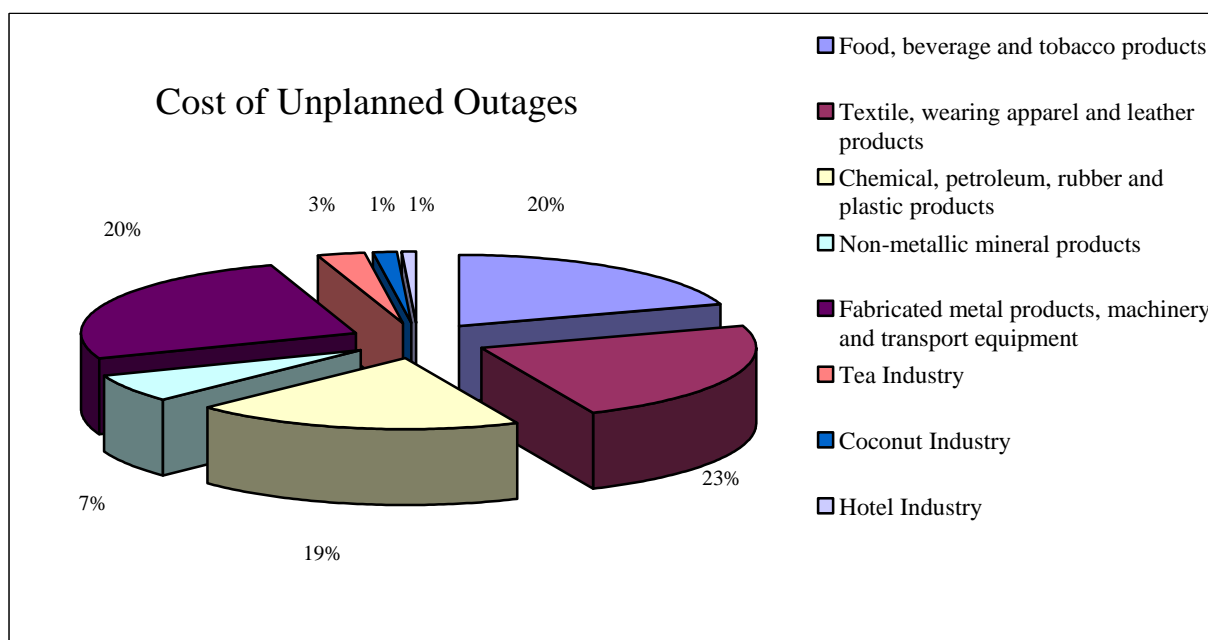Tea Industry

Coconut Industry

Hotel Industry

Figure 4.2: Proportions of Cost of Unplanned Outages

These losses determined for different industry categories vary within a range. The variation of losses in major categories of industries from the average loss level with 90%

confidence for planned outages is given in Figure 4.3. It can be seen that these variations are considerably high. This is mainly due to the wide range of industry installations in terms of the nature of output, electricity intensity and the output capacity, that one finds within each of these industry categories. A similar range of variations can be seen for unplanned outages.
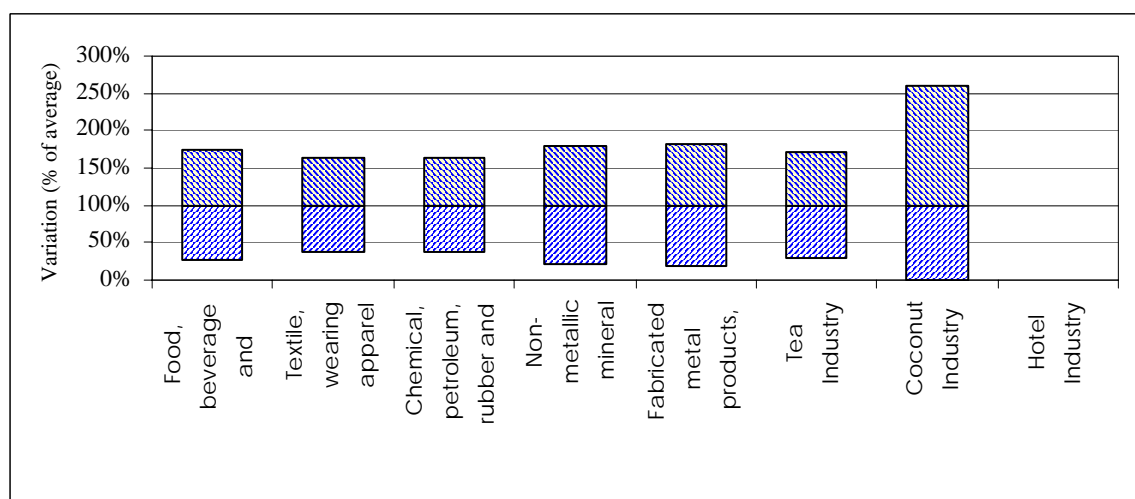

Figure 4.3: Variation of countrywide expected values of losses under planned interruptions

Planned and unplanned power interruptions affect the industries in different ways due to different levels of preparedness associated with these interruption types. It can be seen from Figure 4.4 that the overall planned outages in the industrial sector costs only about **60%** of that associated with the unplanned outages.
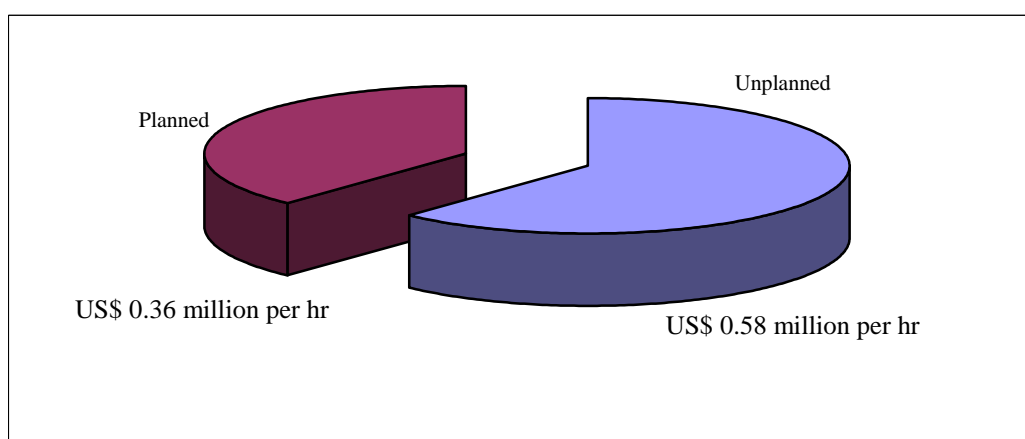

Figure 4.4: Comparison of Cost of Planned and Unplanned Outages

4.2 National Economic Losses

Planned interruptions can be due to scheduled regular maintenance in the power system or may be due to power shortages during times of drought, which drastically limits hydropower input to the generation system in Sri Lanka. During 2001, planned power

interruptions due to power shortages amounted to approximately 300hrs up to early December. Figure 4.5 shows the variation of the impact of planned interruptions on the industrial sector finally affecting the country's economy.
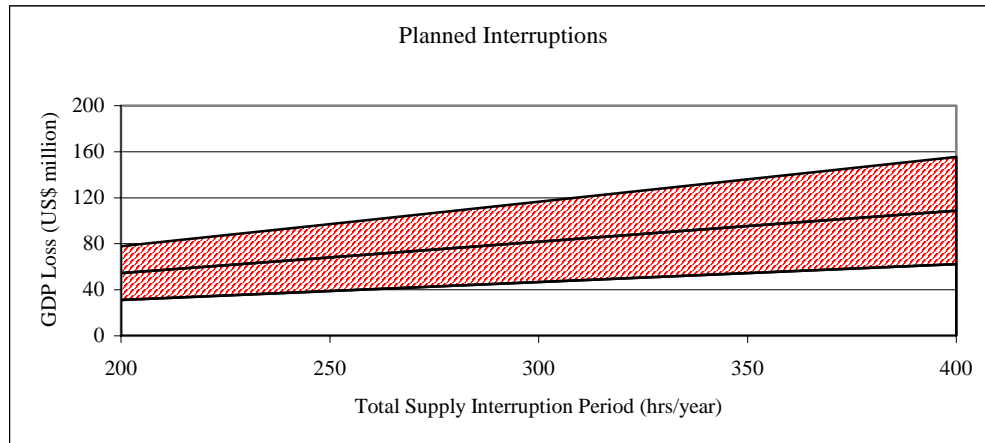

Figure 4.5: Economic Loss Resulting from Planned Power Interruptions in the Industrial Sector

When the interruptions are planned and consumers are informed well in advance, the losses can be minimised, particularly the raw material and manpower losses experienced in some industries. Unplanned interruptions are mainly due to unexpected failures in various parts of the power system or due to the utility's failure to inform the consumers in advance of a planned interruption. Generally these interruptions do not last long and the total period of such losses during a given year is considerably lower in comparison to typical planned outages during the periods of power shortages. Typically, this is about 100 hrs per year on average. The economic losses due to unplanned interruptions in the power system against the total duration of such interruptions are plotted in Figure 4.6. In both these types of interruptions the losses can vary within the band shown in the figures with a **90%** confidence level.
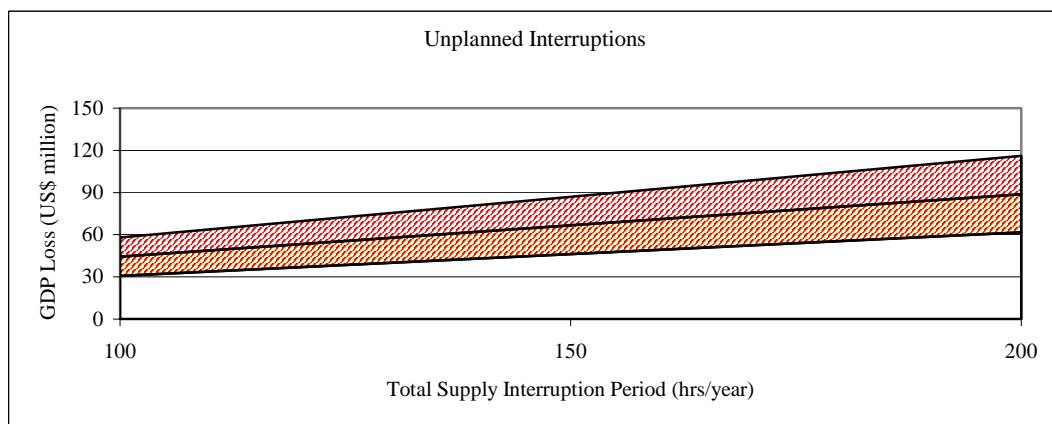

Figure 4.6: Economic Loss Resulting from Unplanned Power Interruptions in the Industrial Sector

The losses due to planned and unplanned interruptions can be expressed in terms of the annual Gross Domestic Product (GDP) of the country. The annual GDP in 2000 in Sri Lanka stood at approximately US$ 12.5 billion (Rs. 1125 billion).[14] Figure 4.7 shows that the outage costs can vary from about **0.2%** to **1%** of the GDP (or US$ 25 –125 million) depending on the duration of such outages. For instance, in 2001 up to late November planned power interruptions due to shortage of system generation capacity amounted to approximately 300hrs. Such a situation can result in about **0.65%** GDP loss or approximately US$ 81 million.
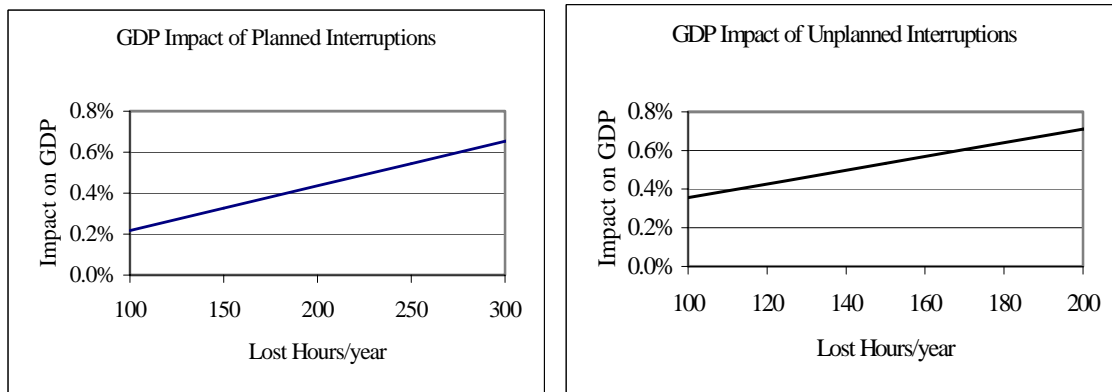

Figure 4.7: Impact of Planned and Unplanned Interruptions on the GDP

The economic losses due to planned and unplanned power interruptions can also be expressed in other forms. One of the commonly used, is the economic loss (in US$) per unit of supply loss (per kWh) identified as the cost of unserved energy. This is calculated dividing the total losses experienced by the total average electricity consumption in the sector during the same period if the supply was available.

The study reveals the costs of unserved energy for the Sri Lanka system are US$ 0.66 per kWh (59.34 Rs./ kWh) and US$ 1.08 per kWh (96.80 Rs./ kWh) for planned outages and un-planned outages respectively.

4.3 Backup Unit Generation (BUG)

With the availability of continuous main grid supply in question, many industries have invested in backup unit generators, even under difficult business climate prevailing today in Sri Lanka. Approximately **92%** of the industries sampled have backup unit generators. While backup unit generators accomplish their main goal, to supply uninterrupted power supply, their inherent inefficiency and increased air pollution are cause for concern. In addition, noise pollution is also a significant factor, particularly when the industries utilizing BUG are located in the vicinity of residential areas. Based on current usage practices, our study has determined that the use of backup unit generators results in approximately **7%** incremental emissions.

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[14] Central Bank of Sri Lanka: Annual Report 2000.

Based on current usage conditions and assuming 300hr power outages annually, the expected backup unit generation during the five years from 2001 to 2005 is shown in Figure 4.8, estimating its use from about 160GWh to 180GWh annually. It is to be noted that the annual electricity generation by the utility is expected to be about 7000GWh this year. The Figures 4.8 and 4.9 also show the incremental emissions of CO2, CO, and Particulates resulting from these backup unit generation units.[15]
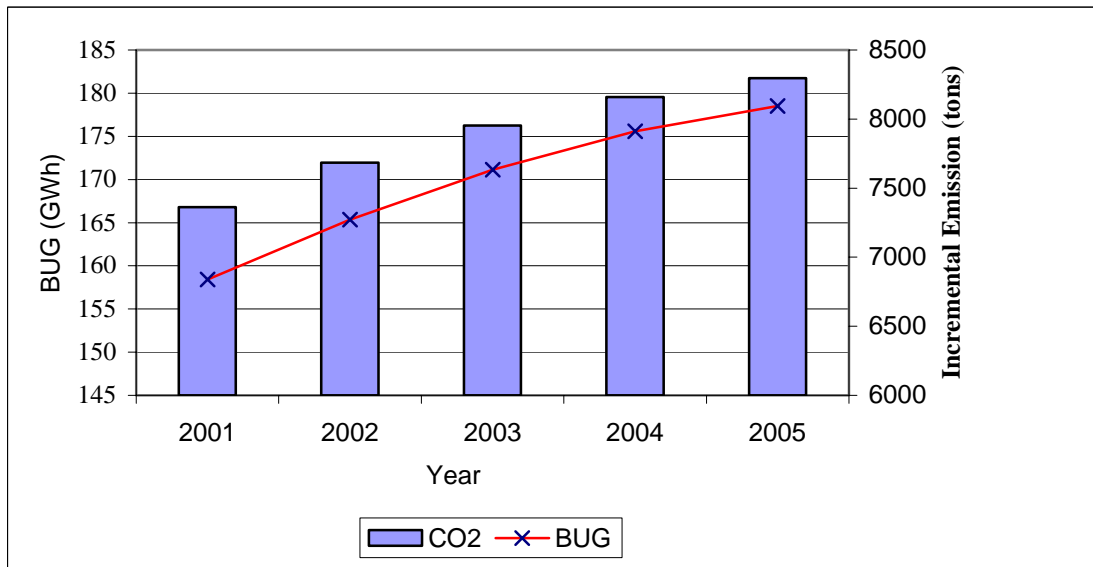
Figure 4.8: Expected Back-up Unit Generation (BUG) and Incremental CO2 emissions
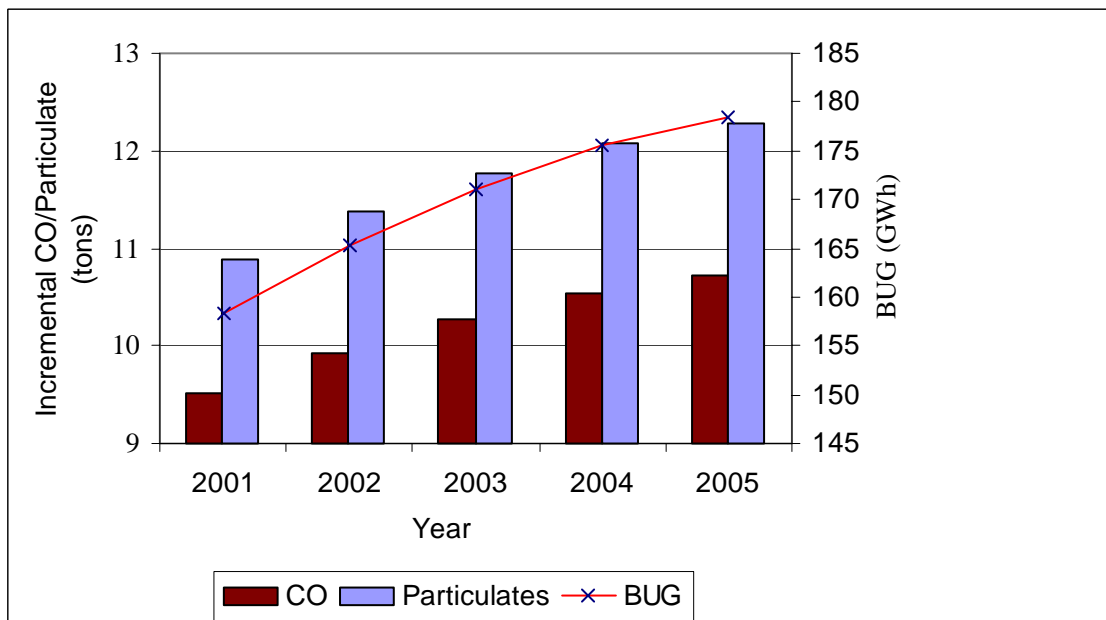
Figure 4.9: Incremental CO and Particulate emissions

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[15] P. Meir, M. Munasinghe, " Incorporating Environmental Concerns into Power Sector Decision-Making; A Case Study of Sri Lanka, The World Bank, 1992.

4.4 Customer Comments

Almost all the consumers surveyed during the study indicated that the cost of electricity is too high. In addition, consumers in some areas complained of the high frequency of unplanned power interruptions. Some of the industries felt that the cost of operating the backup unit generators is too high for them to remain competitive in the market and therefore they are seriously affected during times of long lasting planned power interruptions. Most customers who were part of the sample did not express problems regarding power system harmonics. Power quality sensitive industries (Petroleum) commented that they used backup power at all times and depended on CEB power only under emergency conditions. Several customers did express an interest to pay a little more for the power they receive provided the quality was improved.

The main impact of the power interruptions both planned and unplanned is on the country's economy resulting from the loss of output in the industrial sector. As shown in section 4.2 these losses can be as high as **0.65%** of the GDP under a typical scenario of imposing power interruptions resulting from system generation capacity shortages such as that experienced in 2001. The impact due to unplanned outages can be around **0.3%** of the GDP annually in a typical year when there are no regular planned interruptions such as those in 2001. These losses are therefore significant especially in comparison to the **4.5% - 5%** average GDP growth in the country during the last few years.

At the individual industry level, these interruptions can lead to the closure of some installations, which do not have the benefit of backup unit generation facilities. In addition, installations where production costs become non-competitive because of self-generation conditions could be faced with closure of their businesses. Many small and medium scale industries fall into this category.

Increased power interruption rates, both planned and unplanned, result in individual industries to seek backup unit power when the capital and operating costs become affordable. This situation leads to a large number of industrial installations establishing backup unit generation facilities, while the utility itself is investing in additional generation capacity. Such a scenario where generation capacity is duplicated results in unnecessary and sub-optimal investment in the sector, which will be finally reflected in the electricity tariffs and production costs in individual industries. Already some of the critical industries such the glass industry and petroleum industry, which rely heavily on the continuity of supply, have opted for Backup Unit Generation while keeping grid electricity as the standby supply.

As shown in Section 4.3, the expected total backup unit generation in the Sri Lanka electricity sector will continue to grow during the next five years if the present trend in using such generation facilities continues at existing levels. This means not only increased generation investment but also incremental emissions in the sector, which would badly affect the local environment, particularly in urban centres where most of these industries are located.

Sudden interruption of supply under unplanned outages causes a significant level of momentary losses, which dominates the cost figures, associated with such outages. This is mainly because the consumers are not prepared for such interruptions, particularly the industrial sector that depends heavily on the continuity of electricity supply. Therefore, unplanned outages are always costlier to the consumers than planned outages due to the simple reason that the consumers can adjust their usage patterns to minimise the adverse impacts of planned outages. It is surmised that such problems can be avoided if consumers are given notice, sufficiently in advance, of impending interruptions.

One of the most important factors when trying to attract investors in the industrial sector is the country's ability to provide a reliable supply of electricity at low cost. Therefore, any failure on the part of the utilities to maintain a cheap and more reliable electricity supply would result in investors being driven away from Sri Lanka. Furthermore, advanced industries such as the semi-conductor industry require not only a continuous electricity supply but also a quality supply where the voltage and the frequency of supply are properly maintained. Though the voltage problems and supply harmonics were never so important in the industry sample surveyed during this study due to the absence of such advanced industries, it is important that these problems be addressed in the context of attracting advanced industries. This will provide the right impetus for promoting future industrial sector activities and the development of Hi-Tech industry.

This study has validated, statistically, the hypothesis that poor power quality has an adverse effect on the GDP of a nation. It was however seen that power quality problems of supply interruptions in Sri Lanka, can cause significant losses to the national GDP. It is worthwhile to note that the Electricity Act of 1959 does not provide any stipulations on the power quality. Currently, the only power quality requirements impose ±**6%** Voltage limits and ±**1%** frequency limits.

The study has shown that for an assumed loss of 300 hours of planned power outages per year translates into a US$ 81 million drop in the GDP of Sri Lanka. On similar lines, an assumed 100 hours of unplanned outages per year causes a drop of US$ 45 million in the GDP. It may be noted that the domestic GDP of Sri Lanka, was approximately US$ 12.5 billion in the year 2000.

Further, these losses due to planned and unplanned supply losses can also be represented in the form of economic loss (in US$) per unit of supply loss (in kWh) identified as the cost of increased energy. The study shows that for the Sri Lanka system, these values become US$ 0.66 per kWh (59.34 Rs/kWh) for planned outages and US$ 1.08 per kWh (97.20 Rs/ kWh) for unplanned outages.

While quantifying planned and unplanned outages, this study shows that losses due to unplanned interruptions, inclusive of momentary interruptions, are approximately 1.6 times those due to planned outages. This means that, in the short term, all efforts must be taken to reduce the occurrence of unplanned outages. This supports the idea that the immediate short-term priority is to improve system reliability and establish processes to ensure that all customers know of any planned outages in advance.

Momentary losses formed a significant portion of the losses due to unplanned outages. This supports the idea that the very event of sudden loss of supply is more detrimental to the operation of an industrial installation than the duration for how long the power outage persists. In economic terms, the momentary outage may be viewed as a fixed cost that happens each time there is an unplanned outage that is independent of the duration of the power outage.

Tables 6.1 and 6.2 summarize the impact of poor power quality on a category and subgroup basis respectively. The highest and lowest losses for each type of interruption may best be explained by examination of the actual physical process involved in each case when an outage, planned or unplanned, occurs.

Table 6.1. Highest and Lowest Losses by Category

Type of Outage	Highest Loss	Lowest Loss
Momentary Outage	Food, beverage and tobacco products	Hotel, Tea
Unplanned Outage	Food, beverage and tobacco products	Hotel, Tea
Planned Outage	Fabricated metal products, machinery and transport equipment	Hotel, Tea

Table 6.2. Highest and Lowest Losses by Subgroup

Type of Outage	Highest Loss	Lowest Loss
Momentary Outage	Tobacco, Cement	Hotel, Tea, Liquor
Unplanned Outage	Tobacco, Cement	Hotel, Tea, Liquor
Planned Outage	Cement, Fabricated metal products, machinery and transport equipment	Liquor, Pharmaceutical, Detergent and Other

The study revealed that **92%** of industrial facilities have back up generation capability and that it takes anywhere from 5-15 minutes to get the backup generation process started. In some cases, glass manufacturers, for example, backup power generation units were used for normal operation and power from the utility, CEB, was used under abnormal circumstances. This type of operation of power usage clearly exhibits the lack of faith such customers have on the quality and reliability of the utility supplied power.

In terms of environmental damage, this study has found that use of backup generation causes an increase in emissions by **7%** for each unit supplied. That is, had the same amount of power been produced by the CEB, there would have been **7%** lower emissions. Other non-tangible environmental impacts like noise pollution etc. have been ignored in this study. Assuming 300 hours of backup generation usage in 2001, the incremental emissions are projected to be 7400 tons of CO_2, 9.5 tons of CO and 10.9 tons of other particulate matter. It is expected that the anticipated usage of local generation will increase by **5%** per annum over the next five years. This translates to an expected 8300 tons of CO_2, 10.7 tons of CO and 12.3 tons of particulate matter in the year 2005.

Having quantified the economic impact of poor power quality on the national GDP and having examined the environmental impact of BUG usage, it is useful to indicate possible actions to mitigate this impact. This study has shown that any interruption, planned or unplanned, causes a significant adverse impact on the GDP. In particular an important issue to be resolved lies in the reduction of losses due to poor power quality.

Planned outages are an inevitable consequence of a lack of supply and hence, recommendations related to reducing losses due to this type of outage are more relevant to long-term system planning. Options to properly balance supply and demand with sufficient operating reserves to maintain network security include the following critical aspects.

- On the generation side, more generation plants must be built in the light of the increased demand. To ensure that such generation is built, several schemes may be considered. Private sector participation in electricity generation using BOOT (Build Own Operate and Transfer), BOO (Build Own and Operate) and BOT (Build Operate and Transfer) schemes, for example, may be worthwhile options. From a procedural point of view, streamlining the process of capacity addition, particularly at the decision making level is an essential step in getting projects such as these online in a short period of time. In the long-term, it may be worthwhile to examine plans that reduce the dependence on limited hydro resources and explore the use of other sources such as LNG and Nuclear for example.

- On the demand side, reduction of effective demand on the system is a viable alternative. This could be achieved by means of promoting the use of more efficient end-use equipment, and encouraging customers to reduce their dependence on the utility supply. Use of local backup generation should only be during the times of power shortages in the system.

- On the transmission side, infrastructure needs to be built and operated more efficiently. Use of Supervisory Control and Data Acquisition (SCADA) and advanced Energy Management Systems (EMS) could help the CEB to enhance system operations at all levels. Provision of wheeling arrangements, whereby excess generation at the customer level may be delivered to other power starved regions, is also an attractive option, which needs to be seriously considered.

Unplanned outages, on the other hand, inevitably occur due to poor system reliability. Since, unplanned outages account for a significant portion of all outages, dealing with the problem of unplanned outages is very critical. Most unplanned outages can be avoided by improving system reliability by considering the following aspects:

- On the generation side, regular and periodic maintenance of generator equipment is absolutely necessary to ensure generator unit availability. Generator protection schemes must be overhauled and its operation must be secure

- On the transmission and distribution side, system reliability must be enhanced. This includes using meshed circuits as opposed to radial feeders, using underground cables in critical areas that are prone to weather related problems, providing multiple feeds to critical customers and enhancing protection schemes to detect and clear faults occurring in the system. In this context, more emphasis must be placed on the maintenance of distribution equipment as it has been proved statistically that outages usually occur as a result of problems on the distribution side.

- In all cases, unplanned outages may be reduced by the use of SCADA systems that will empower the operator to monitor and observe system conditions and flows, and conduct supervisory controls remotely.

- It is imperative that all planned outages are communicated well in advance to the customers so that suitable action can be taken in time. In this context, establishing a Customer Support Centre that has access to an Outage Management System will be beneficial to all customers.

The Electricity Act (1959) needs to be amended to provide for standards on the power quality. It must include issues related to the number and duration of outages that a customer is permitted to experience by providing limits on SAIFI and CAIDI indices. In this context, it may be worthwhile to also examine aspects of power system harmonics and other such power quality phenomena and establish suitable criteria. Imposing stringent conditions on power quality will enhance the possibilities of attracting investment on high-tech industries in the future.

Anticipated backup unit generation figures show an increase in its usage during the next five years. And, given that the environmental impact of producing a unit of power by the CEB is lesser than that of producing the same unit of power locally with small backup generating units, capacity additions by the CEB must be taken as an environmentally cleaner alternative.

Finally, it is recommended that studies on enhancing the reliability of the Sri Lanka national power grid be undertaken. This includes a study of existing system planning and operations. Studies must examine ways of improving the overall system efficiency and reducing losses. Studies that involve exploring the possibility of establishing an interconnection between the Sri Lanka grid and the Indian power system and subsequent trading mechanisms may also be worthwhile in addressing the power quality issues in Sri Lanka.

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Electricity Act, Government of Ceylon, 1959.

Appendix A

Planned & unplanned power supply interruptions and low voltage have been affecting various consumer groups of the Sri Lanka electricity industry from time to time. Out of these consumers industrial sector including those such as the tea industry is one of the more important sectors to be seriously impacted due to power interruptions as a result of, mainly the supply shortages occurring under low rainfall conditions. This study, which has been initiated by NEXANT SARI/Energy under the South Asia Regional Initiative for Energy (SARI/E), initiated by the United States Agency for International Development (USAID), is aimed at estimating the economic impact of such supply interruptions in the industrial sector.

The questionnaire attached herewith is aimed at obtaining required information, for the above study. The enumerators, who just completed their final year examinations in the Electrical Engineering undergraduate programme and trained for this purpose, are expected to complete the questionnaire with your assistance. The study team greatly appreciates your kind cooperation during this work, particularly by providing necessary data and answering specific questions put forward by the enumerators.

Dr Priyantha D C Wijayatunga

Local Study Team Leader

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I. 1. Name and Address of the Institution

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I.2. Code

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II. Name and Designation of the person providing information

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III. Industry Category and final Product

Please tick where appropriate

Category	(√)	Final Product (*Please write*)
Food, beverage and tobacco products		
Food and Other		
Liquor		
Beverage		
Tobacco Products		

Textile, wearing apparel and leather products		
Apparel		
Textile		
Leather		

Chemical, petroleum, rubber and plastic products		
Chemicals, Paints and Fertilisers		

Rubber		
Plastic and PVC		
Pharmaceuticals, Detergent and Other		
Petroleum		

Non-metallic mineral products		
Diamond Processing		
Ceramic Products		
Cement		
Building Materials and Other		

Fabricated metal products, machinery and transport equipment		

Tea Industry		

Coconut Industry		

Hotel Industry		

IV. Electricity Information

Average monthly Energy Consumption (kWh/month)	Monthly Maximum Demand (kVA)	Average Monthly Electricity Cost (Rs)

V. Financial Information

Average Annual Turnover (Rs)	Average Annual Expenditure (Rs)	* Average Annual Value Addition (Rs)

If this is provided other information not required

VI. Loss Information – *Provide losses per hour basis where appropriate*

Momentary Loss of Supply (less than 1/2hr duration)

	Physical loss (No Units.)	Revenue Loss (Rs) Per Unit
Loss of raw material		
Loss of Output		
Loss of Manpower		
Time duration of Backup unit Generator Operation		

Unplanned longer Supply Interruptions

	Revenue Loss (Rs)				
Interruption time	0 – ½ hr	½ hr - 1hr	1 - 2hrs	2 - 4hrs	4 - 8hrs
Loss of raw material					
Loss of Output					
Loss of Manpower					
Time duration of Backup unit Generator Operation					

Disturbances to the production process due to voltage variations (greater than 6% of rated voltage)

	Revenue Loss (Rs)				
Duration of Voltage Variation	0 – ½hr	½ - 1hr	1 – 2hrs	2 – 4hrs	4 – 8hrs
Loss of raw material					
Loss of Output					
Loss of Manpower					
Time duration of Backup unit Generator Operation					
Damage to equipment					

Other significant supply problems such as supply harmonics

	Revenue Loss (Rs)				
Duration of Problem	0 – ½hr	½ - 1hr	1 – 2hrs	2 – 4hrs	4 – 8hrs
Loss of raw material					
Loss of Output					
Loss of Manpower					
Time duration of Backup unit Generator Operation					
Damage to equipment					

Planned Supply Interruptions

	Revenue Loss (Rs)				
Interruption time	0 - 1/2hr	½ - 1hr	1 - 2hrs	2 - 4hrs	4 - 8hrs
Loss of raw material					
Loss of Output					
Loss of Manpower					
Time duration of Backup unit Generator Operation					

Supply Restrictions (eg Ban on using air-conditioners)

	Revenue Loss (Rs/hr)
Loss of raw material	
Loss of Output	
Loss of Manpower	
Backup unit Generator Operated?	

Other Comments **(eg. Impact of electricity cost on the industry)**

Backup unit Generator Information

Manufacturer	
Generator Capacity (kW)	
Expected lifetime	
Initial Capital Cost (Rs)	
Annual maintenance Cost (Rs/Year)	
Average Fuel Consumption (liters/kWh)	
Fuel Consumption Cost (Rs/kWh)	
Other overhead costs (Rs/Month)	
Emission Factors (kg/kWh)	
CO_2	
CO	
Sox	
Nox	
Particulate emissions	